EVA Human Health and Performance Benchmarking Study Overview and Development of a Microgravity Protocol

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Multi-Disciplinary Team

HH&P

- EVA Physiology
- Anthropometry & Biomechanics Facility
- Exercise Physiology & Countermeasures
- Neurosciences
- Behavioral Health & Human Factors
- Biostatistics

Engineering

- Spacesuit & Crew Survival Systems
- EVA Tools
- ARGOS

Operations

- EVA Office
- Medical Operations
- Crew Health & Safety Program
- Astronaut Office
- EVA Operations

Other Partners

- MIT's Department of Aero & Astronautics
- Astromaterials Research & Exploration Science

Study Objective

- The primary objective of this study is to develop a protocol to reliably characterize human health and performance metrics for individuals working inside various EVA suits under realistic spaceflight conditions.
- Expected results and methodologies developed during this study will provide the baseline benchmarking data and protocols with which future EVA suits and suit configurations (eg, varied pressure, mass, center of gravity [CG]) and different test subject populations (eg, deconditioned crewmembers) may be reliably assessed and compared.
- Results may also be used, in conjunction with subsequent testing, to inform fitness-for-duty standards, as well as design requirements and operations concepts for future EVA suits and other exploration systems.

HRP Risks and Gaps

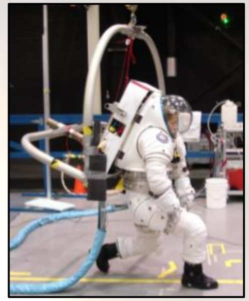
	HRP Gap	Relevance to Gap
Primary Gaps – inform primary study design	EVA7: How do EVA suit system design parameters affect crew health and performance in exploration environments?	Expected results will provide data and methods with which future EVA suits and different suit configurations (e.g. varied pressure, mass, CG) may be reliably compared in subsequent tests. Results may also inform requirements and operations concepts for future EVA suits and other exploration systems.
	EVA8: What are the physiological inputs and outputs associated with EVA operations in exploration environments and how can they be modeled?	Expected results will characterize metabolic and relevant consumable benchmark data for a standard set of EVA tasks. Results may also inform design requirements and operations concepts for future EVA suits and other exploration systems.
Secondary Gaps – inform supplemental aspects of study or benefit from study design	EVA11: How do EVA operations in exploration environments increase the risk of crew injury and how can the risk be mitigated?	This study will provide an opportunity to use the Crew Health and Safety suit exposure questionnaire in the planetary gravity environment and will provide benchmark data on the likelihood and consequence of symptoms and injuries associated with EVA operations in different suits.
	EVA6: What crew physiological & performance capabilities are required for EVA operations in exploration environments?	This study will provide health and human performance data for a comprehensive set of exploration EVA tasks. Standardized data and methodologies will also enable comparison with different subject populations such as deconditioned crewmembers in subsequent tests, which may inform fitness-for-duty standards.
	M4: Establish muscle fitness standards for successful completion of mission tasks. A4: Establish aerobic fitness standards for successful completion of mission tasks.	Strength, muscle performance, and aerobic fitness data from subject characterization may be used to predict EVA task performance. Standardized data and methodologies will also enable comparison with different subject populations such as (simulated and/or actual) deconditioned crewmembers in subsequent tests.
	SM6.1: Determine if sensorimotor dysfunction during and after long-duration spaceflight affects ability to control spacecraft and associated systems.	Results will provide baseline data on how being in an EVA suit affects sensorimotor performance. Standardized data and methodologies will also enable comparison with different subject populations such as deconditioned crewmembers in subsequent tests.
Tertiary Gaps – pilot data & feasibility	BMed3: Identify and quantify the key threats to and promoters of mission relevant behavioral health and performance during autonomous, long duration and/or long distance exploration missions.	Results will provide pilot data on how being in an EVA suit affects neurocognitive performance and if it can be measured reliably and accurately while suited.

Specific Aims

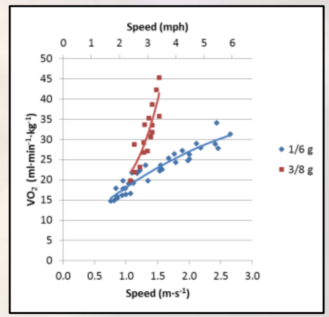
- ***Specific Aim 1:*** Define a set of standardized EVA benchmarking tasks

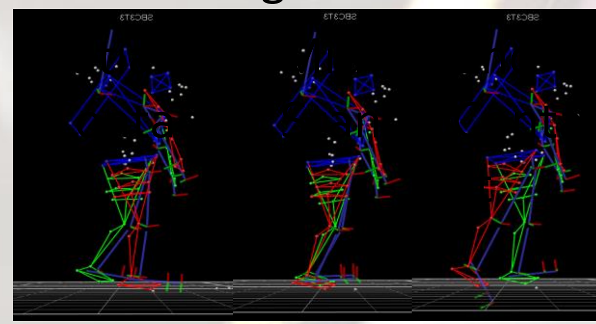






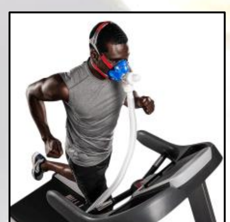
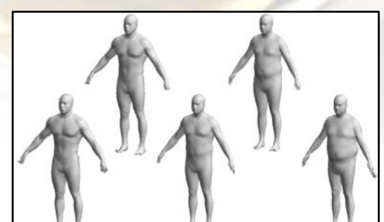

- ***Specific Aim 2:*** Develop valid and reliable metrics and methodologies to accompany the benchmarking tasks





- ***Specific Aim 3:*** Develop a methodology for quantifying suit fit

- ***Specific Aim 4:*** Characterize the anthropometry and physiology of the subject population


Task Identification and Downselect

Compile Candidate Task Inputs

- EVA Office
- Crew & Thermal Systems Division
- Anthropometry & Biomechanics Facility
- EVA Physiology Lab
- Functional Task Test (JSC Neuroscience Lab)
- Field Test (JSC Neuroscience Lab)
- Critical Mission Tasks (JSC Exercise Lab)
  - Procedure Analysis & Decomposition
- Massachusetts Institute of Technology
- Human Integration Design Handbook
- Constellation Space Suit Requirements Document

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Preliminary Down-Selection Criteria

- Use of task in current and/or previous tests
- Reliable task performance data from previous tests
- Availability of task-related hardware / mock-ups
- Duplicative / redundant tasks
- Quality of available task performance measures
- Similarity to anticipated EVA tasks
- Evidence of general task performance as relevant to EVA tasks
- Feasibility of suited data collection
- Task specific to glove design

Down-Select

Down-Selected Task Grouping

Isolated Joint Testing

- Strength
- Range of Motion

General Functional Performance

- Reach
- Strength
- Agility
- Balance
- Coordination

EVA Tasks

- Micro-gravity
  - Upper-Body
- Planetary
  - Upper-Body
  - Lower-Body
  - Whole-Body

ARGOS – Microgravity Conditions

Microgravity Protocol Layout

Versatile Neutral Capability Horizontal Interface (VNCHI)

Unsuited

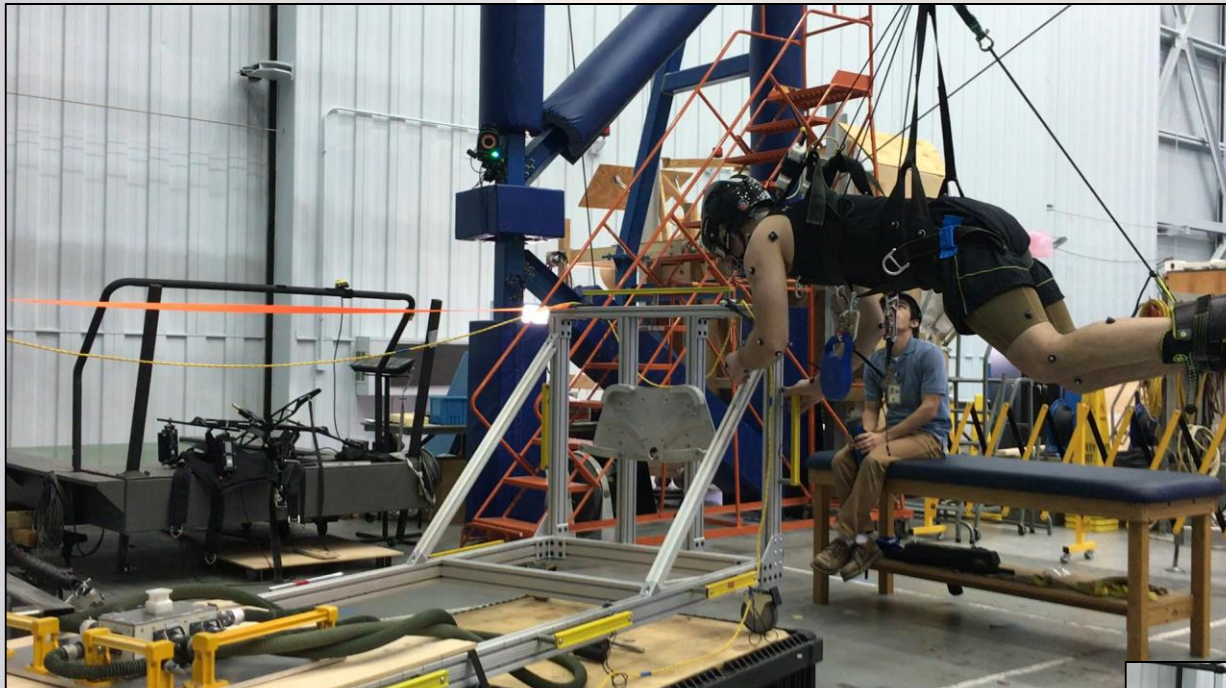
EMU

Mark III

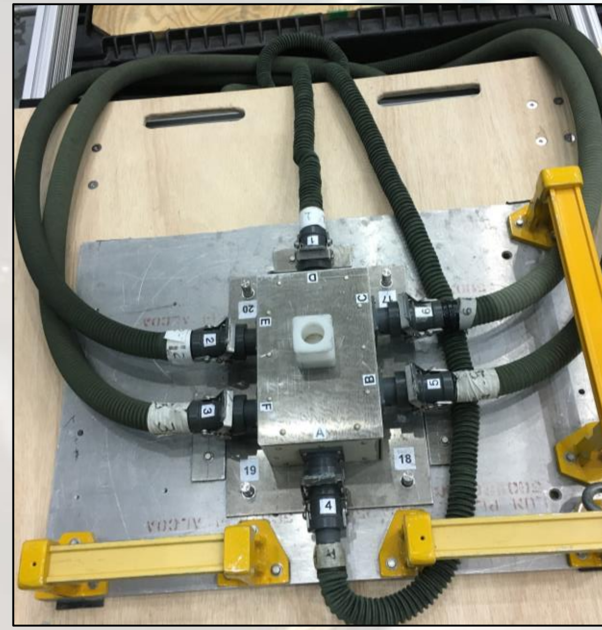
Z-2

Translation Circuit

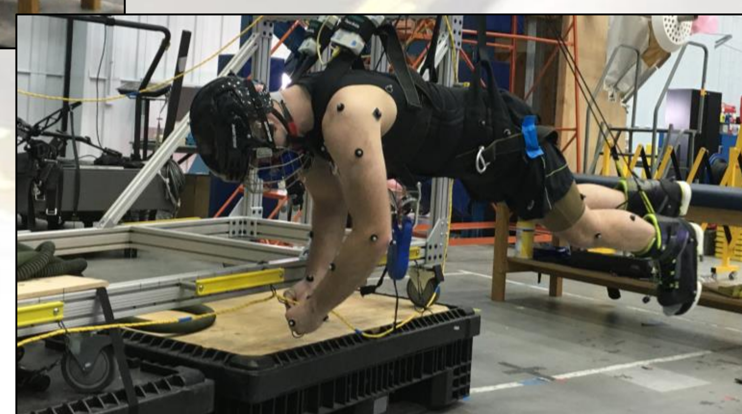
Translation Video



Quick Disconnect Task Board



Cable Routing



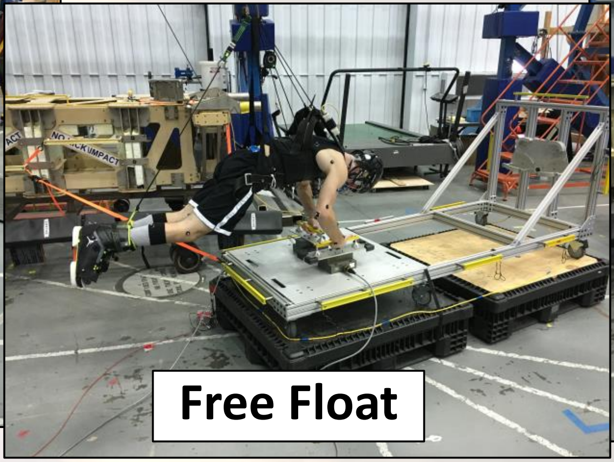
Microgravity Tasks

Work Envelope

Functional Task

Reach Envelope

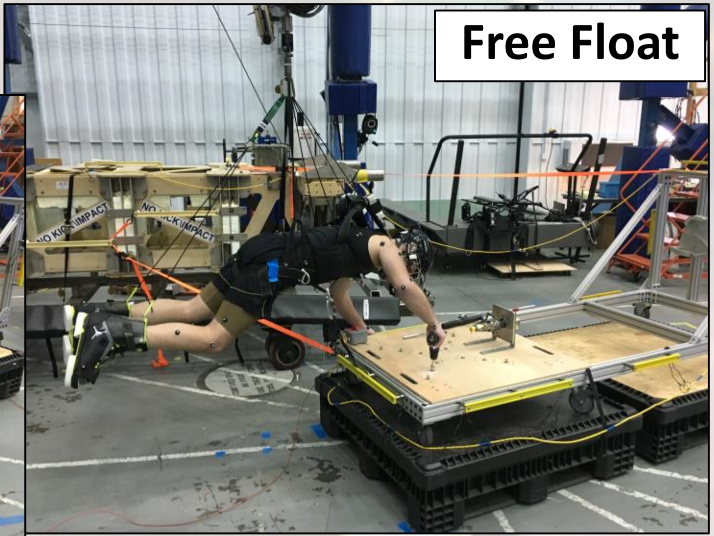
Functional Strength



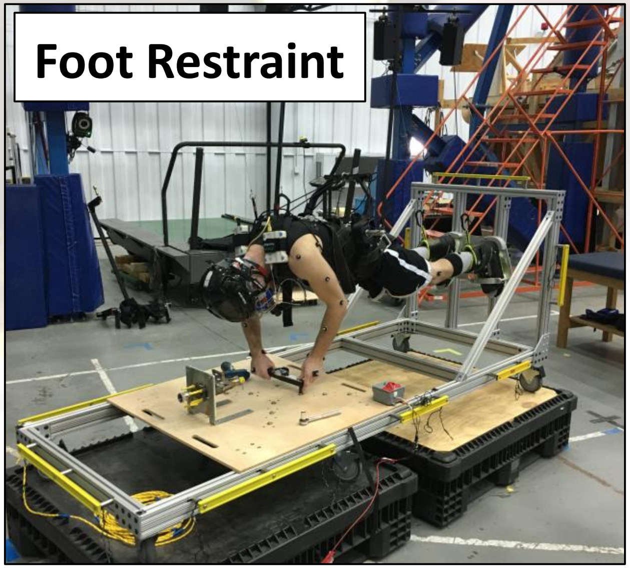
Free Float

Foot Restraint

Bolts Task Board



Free Float



Foot Restraint

Task Timeline

Free Float	Translation Circuit Familiarization
	Translation Circuit #1
	Bolt Task Board Familiarization
	Bolt Task Board #1
	Translation Circuit #2
	Bolt Task Board #2
	Translation Circuit #3
	Bolt Task Board #3
	Wide Reach Translation
	Strength Testing
Break – Change Gimbals	
Foot Restraint	Strength Testing
	Bolt Task Board
	Functional Work Envelope
	Shoulder ROM
	Reach Envelope

Data Metrics

- Metabolic
  - Metabolic rate
  - Metabolic cost/time to completion
  - Heart rate
- Motion Capture
  - Isolated joint range of motion
  - Path length
  - Body position
  - Reach & work envelope
- Subjective Ratings
  - RPE
  - Discomfort
  - Task acceptability
  - Simulation quality
  - Muscle fatigue
- Force
  - Maximum isometric

Tasks Considered But Not Included

Eliminated Tasks	Reason
Translate through hatch	Logistics/cost for what is expected to be a low sim quality task
Small object transfer	Object would just hang from suit, not likely to get useful data
Translate along a boom (exploration)	Similar data will be captured in the translations already planned
BRT operations	similar data will be captured with APFR
Functional suit reach	Assumed to be part of suit design requirements
Functional geology	Struggles with the VNCHI gimbal did not facilitate a task that stressed different body positions and station keeping

Protocol Assessment Questionnaire (PAQ)

- Provides consistent framework to review each test day
- Protocol changes must be reviewed by critical stakeholders and agreed upon by study team
- PAQ has inputs from both the subject and the study team
- Uses Acceptability and Simulation Quality Scales as anchors

Examples of deficiencies: inefficiency, high mental workload, increased physical exertion,

Totally Acceptable		Acceptable		Borderline		Unacceptable		Totally Unacceptable		No Rating
No improvements necessary and/or No deficiencies		Minor improvements desired and/or Minor deficiencies		Improvements warranted and/or Moderate deficiencies		Improvements required and/or Unacceptable deficiencies		Major improvements required and/or Totally unacceptable deficiencies		Unable to assess capability
1	2	3	4	5	6	7	8	9	10	NR

No Limitations	Minor Limitations	Marginal Limitations	Significant Limitations	Major Limitations	No Rating
Simulation quality (e.g. hardware, software, procedures, comm, environment) presented either zero problems or only minor ones that had no impact to the validity of test data	Some simulation limitations or anomalies encountered, but minimal impact to the validity of test data	Simulation limitations or anomalies made test data marginally adequate to provide meaningful evaluation of test objectives (please describe)	Significant simulation limitations or anomalies precluded meaningful evaluation of major test objectives (please describe)	Major simulation limitations or anomalies precluded meaningful evaluation of all test objectives (please describe)	Unable to assess simulation
1	2	3	4	5	NR

Schedule

- FY16
  - Microgravity Unsuited Feasibility
- FY17
  - Subject Characterization
  - Microgravity EMU Feasibility
  - Microgravity Unsuited and EMU Data Collection
  - Planetary Unsuited, Mark III and Z-2 Feasibility
  - Planetary Unsuited, Mark III and Z-2 Data Collection
- FY18
  - Microgravity Mark III and Z-2 Feasibility
  - Microgravity Mark III and Z-2 Data Collection